

PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in or relating to Polyphase Dynamo-electric Machines incorporating Protection against Overheating

We, WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY, of 40, Wall Street, New York 5, State of New York, United States of America, a Corporation organised and existing under the Laws of the State of Delaware, in said United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to polyphase dynamo-electric machines incorporating protection against overheating.

Polyphase dynamo-electric machines have usually been protected against overheating by means of thermal overload relays having a thermally responsive element, usually a bimetallic element, heated either directly by the current of the protected machine or by a heater carrying the current, so that the relay responded solely to the current. Such relays have usually been mounted remote from the machine itself, and frequently in the same enclosure or cabinet as a motor starter or other control equipment. Relays of this type do not give entirely satisfactory or adequate protection, however, since the relay responds only to the current, and the thermal characteristics of the relay do not, and obviously cannot, match those of, for example, a motor, so that the thermal response of the relay differs from that of the motor. Thus, the relay is affected differently from the motor by changes in ambient temperature, and the response of the relay may also be affected by heat from other adjacent devices, or by air currents and similar conditions which do not affect the motor. Difficulty in calibration of the relay, and the necessity of a large number of different types and sizes of heaters for different motor designs, also make it difficult

to properly apply conventional protective relays and to obtain the desired protection. The conventional relays, therefore, are not satisfactory since it is not possible to obtain sufficiently close protection, and in some circumstances the relay will operate when the motor is still below the maximum safe temperature, so that it is unnecessarily stopped, while under other circumstances the relay may allow the motor to become overheated before it operates.

Inherent thermal protection has been extensively and successfully used in single-phase motors. In this type of protection, a thermally responsive device, usually a bimetallic element, is mounted directly in or on the motor, so that it responds directly to the motor temperature, and usually is also heated by or in response to the motor current. Very close and effective protection is obtained in this way, but this type of protection has not been applied to three-phase machines because at least two relays would be needed, in order to open two lines, and three relays would be necessary to obtain complete protection under all conditions, since on certain types of external faults a three-phase motor may operate on one phase with excessive current in the one phase which may be that not associated with a relay. The cost and complication of these arrangements has made it impractical to apply this type of protection to three-phase machines. Furthermore, if the relays are mounted in the machine to be as close as possible to the motor windings, so as to follow the temperature changes accurately, they are enclosed in the motor and are not accessible for servicing without partially disassembling the motor. Thus, the conventional inherent thermal protection as used in single-phase motors is not satisfactory for polyphase machines.

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In addition, it has been proposed to provide thermal protection for a polyphase motor by means of a thermally responsive device which is either disposed in the winding or is heated by resistance heaters connected in the line leads.

The principal object of the present invention is to provide inherent thermal protection for a polyphase dynamo-electric machine which will reliably protect the machine against overheating under any condition.

According to the present invention there is provided a polyphase dynamo electric machine having a thermally responsive protective device comprising tube means containing a liquid which vaporizes to actuate machine de-energising contacts at the safe maximum temperature of the machine, the complete tube means being disposed in close thermal relation to the windings of all the phases of the machine so as to be heated by the heating effect of current flowing in said phases, and individual parts of said tube means being adapted to be individually and additionally heated by the currents flowing in the respective phases of the machine.

The invention will become apparent from the following detailed description of several exemplary embodiments thereof illustrated in the accompanying drawings.

Fig. 1 is a perspective view, partly broken away, showing a thermally protected machine;

Fig. 2 is a view in elevation showing the thermally responsive protective device;

Figs. 3 and 4 are schematic diagrams showing the connections of the device to star and delta-connected motors respectively; and

Figs. 5 and 6 are similar diagrams showing the connections of the device to dual-voltage star and delta connected motors, respectively.

Fig. 1 shows a thermally protected electric motor embodying the invention. An alternating-current induction-motor has been shown for the purpose of illustration, but it will be understood that the protective device is generally applicable to polyphase dynamo-electric machines of any type. The motor shown in Fig. 1 includes a frame structure 1 in which is supported a stator core 2 with windings 3 disposed in slots in the core in the usual manner, with the end turns of the windings extending beyond the core. The motor also has a rotor 4 mounted on a shaft 5 supported for rotation in bearings carried in end-brackets 6.

The motor is protected against overheating by means of a thermally responsive device 7, which is shown more clearly in Fig. 2. As there shown, the device 7 consists

of a length of electrically and thermally conductive tubing 8, which is preferably electrically insulated by glass sleeving 9 or other insulating material. The tube 8 is made of a conducting material which is selected to have the proper resistivity to give the desired heating effect in response to the currents expected in the particular motors on which the device is to be used. The tube 8 contains a vaporizable liquid which boils at approximately the maximum safe temperature which the machine windings are to be allowed to reach. Any suitable liquid having its boiling point in the desired range may be utilized. For the usual organic insulation, the maximum safe temperature is of the order of 95°C. to 100°C., and a liquid having its boiling point in this range, such as water or propyl alcohol, may be used. If the machine insulation is of a type which can be permitted to reach higher temperatures, a liquid having a higher boiling point can be used. One end of tube 8 is closed and the other end terminates in an expandable capsule or bellows device 10 which is arranged to actuate normally closed contacts 11 to open the contacts when the device 10 is expanded. It will be seen that when the tube 8 is heated sufficiently to vaporize the liquid in it, the device 10 will be expanded and cause the contacts 11 to open. The device 10 and contacts 11 are preferably enclosed in a housing 12.

The tube 8 is not continuous but is interrupted by two electrical insulators 13 and 14 which may for example be made of glass, or porcelain. The insulators 13 and 14, as shown in Fig. 2, are tubular insulators in which the ends of the adjacent sections of the tube 8 are received and held, so that a continuous passage is provided from one end of the tube to the other, but the tube is electrically discontinuous. The insulator 13 is located adjacent the device 10, so as to insulate the device 10 from the remainder of the tube. The insulator 14 is located so as to divide the tube into the sections of unequal length, the insulator 14 being disposed approximately one-third of the distance from the closed end of the tube to the insulator 13.

Electrical connectors 15 and 16 are provided adjacent the closed end of the tube 8 and the insulator 14, respectively. These connectors may be soldered or otherwise joined to the tube 8, and may be of any desired type which will permit electrical connections to be made to the tube. Similar connectors 17 and 18 are provided adjacent the opposite side of the insulator 14 and the insulator 13, respectively, and a connector 19 is placed substantially halfway between the connectors 17 and 18. The connectors are arranged so as to divide the

tube into three sections of approximately equal length and electrical resistance, the sections being between the connectors 15 and 16, the connectors 17 and 19, and the connectors 19 and 18. A connecting wire or jumper 20 which, as shown, is constituted by an extension of the connector 16, is provided for joining the connectors 16 and 19. This wire 20 is needed in some electrical connections of the device and is omitted in other connections, as will appear hereinafter.

The device 7 is applied directly to the end-turns of the motor windings 3 in the manner shown in Fig. 1. Thus, the tube 8 is wrapped circumferentially around the end turns in direct contact with them, so as to be in close thermal relation to the windings, the conductive tube being electrically insulated from the winding conductors by the winding insulation and the insulation 9 of the device. The end of the tube with the device 10 and contacts 11 extends out through the motor frame and the housing 12 is mounted in the junction box 21, so that it is readily accessible from the outside of the motor. If desired, the other end of the tube within the motor may be bent into contact with the bearing, as indicated at 22, to provide protection against overheating of the bearing. It will be evident that the tube 8 is in close thermal relation with the windings 3, so that its temperature closely follows the temperature of the windings, and when the tube is heated to the boiling point of the liquid in it, the liquid will be vaporized, causing the device 10 to expand and open the contacts 11. Thus, the device 7 operates to open its contacts in response to heating of the windings to a predetermined maximum safe temperature.

Heating of the tube 8 directly by conduction from the motor windings provides adequate protection against overheating caused by overloads and some other conditions, but under stalled or locked-rotor conditions, the windings heat so rapidly that transfer of heat to the tube may not be fast enough to give adequate protection. In order to provide protection under these conditions, the tube 8 is also heated directly by the motor current. Fig. 3 shows the manner in which the tube is electrically connected to the windings of a star-connected motor. This figure shows a three phase motor having phase windings 23, 24 and 25, connected to a three-phase line 26 by means of a contactor 27. The other ends of the windings 23, 24 and 25 are connected to the connectors 15, 17 and 18, respectively, and the connectors 16 and 19 are joined by the electrical connection 20 which in this instance is shown as being integral therewith. Each section of

the tube 8 is thus connected in series with one of the phase windings to carry the phase current, and all three sections are connected to the connector 19 which forms the neutral point.

The contacts 11 of the device 7 may be connected in the control circuit of the motor in any desired manner. As shown in the drawing, the contactor 27 is actuated by a coil 28 connected across one phase of the line 26 and is controlled by a start pushbutton 29 and a stop pushbutton 30. The motor is started by momentarily closing the start button 29, which energizes the coil 28 and closes the contactor 27, the contactor being held in by a maintaining contact 31. The motor is stopped by opening of the contacts 11 or by actuation of the stop pushbutton 30, either of which interrupts the circuit of the coil 28 and allows the contactor 27 to open.

It will be seen that the motor will be stopped upon heating of the tube 8 to the predetermined maximum safe temperature either by direct conduction of heat from the windings or by heating by the current flowing through the three sections of the tube. Complete protection is obtained in this way under all conditions. Thus, heating due to an overload causes the winding temperature to rise and heat the tube 8 directly. Stalled or locked rotor conditions cause excessive currents in the windings, which flow through the sections of the tube and heat it rapidly enough to cause operation in time to protect the motor. Protection is also obtained against single-phase operation of the motor. Such operation may be caused by interruption of one of the lines 26 external to the motor, which will result in the motor running as a single-phase motor with two of the phase windings in series across the remaining two lines and with excessive current flowing in the one phase winding which is energized. Single-phase operation may also result from blowing of a fuse on the primary side of a three-phase transformer supplying the motor. Current will then flow through two of the phase windings in parallel and return through the third phase, which will thus be carrying an excessive current. Since each section of the tube carries the current of one of the phase windings, the tube will be heated sufficiently to cause operation by excessive current in any phase and complete protection is provided under these conditions.

Fig. 4 shows the manner of connecting the device 7 to a delta-connected motor having three-phase windings 32, 33 and 34. The windings 32 and 34 are connected at one end to each other and to the line, and the other ends of these windings are connected to the connectors 17 and 15,

respectively, of the device 7. One end of the winding 33 is connected to the connector 188 and the other end is connected to the second line and to the connector 16, the connector 20 being omitted in this connection. The connector 19 is connected to the third line. It will be seen from Fig. 4 that this results in the three windings being connected in delta with one section of the tube 8 in series with each phase winding, so that full and complete protection is obtained, under all conditions, in the same manner described above in connection with Fig. 3. In Fig. 4, the device 10 is shown as actuating multiple contacts 35, instead of the single contact previously described, the contacts 35 being connected directly in the supply line so that operation of the device opens the line directly. It will be understood that in either of the connections of Figs. 3 or 4, multiple contacts might be used in the manner shown in Fig. 4, or a single contact might be connected in a control circuit as shown in Fig. 3, depending upon the size of the motor and the magnitude of the currents to be interrupted.

The device 7 is usable with dual-voltage motors as well as with single-voltage motors and can readily be connected so that the usual standard connections of these motors may be used without change. Dual-voltage motors are provided with windings which have two sections in each phase, the sections of each phase being connected in series for operation on the higher voltage and in parallel for operation on the lower voltage. In applying the device 7 to a star-connected dual-voltage motor, the connections are made as shown in Fig. 5, which corresponds to Fig. 3. As shown in Fig. 5, for the low-voltage connection, one section 37 of each of the three phases is connected to the relay in the same manner as the windings shown in Fig. 3, and the other sections 36 of each phase are connected in star to a neutral point 38, so that the two sections of each phase are in parallel, with a section of the tube 8 in series with one section of each phase winding. For high-voltage operation the two sections 36 and 37 of each phase are connected in series and connected to the device 7 in exactly the same manner as in Fig. 3. It will be apparent that protection is provided in this way in the same manner previously described, since the tube 8 will carry the same currents in each connection and the same device 7 is, therefore, usable for both high and low voltage connections.

Fig. 6 corresponds to Fig. 4 and shows the low-voltage connection for a dual-voltage delta-connected machine. In this connection, one section 39 of each phase is

connected in delta to the corresponding sections of the other phases and to the line. One end of each section 40 of each phase is connected to the device 7, in the same manner as in Fig. 4, and the other end of each section 40 is connected to the corresponding section 39. It will be evident from the drawings that each phase consists of two paralleled sections with a section of the tube 8 in series with one section. For the high-voltage delta connection, the winding sections 39 and 40 of each phase are connected in series, and the connections to the device 7 are made in the manner shown in Fig. 4. Thus, the relay is applicable to dual-voltage motors, either star or delta connected, in a simple manner which makes it possible to use the standard connections for motors of this type.

It should now be apparent that inherent thermal protection has been provided by means of a relatively simple and inexpensive thermally responsive device 7 which is applicable to polyphase motors to provide complete protection under all conditions. The thermally responsive device 7 is readily applied to the end turns of the winding and may be put in place before the final varnish impregnation and baking of the winding, if desired, so that the varnish helps to hold it in place and in good thermal relation with the windings. The capsule or bellows device and contact assembly of the device 7 extend outside the motor frame and are readily accessible so that the contacts may be serviced easily without disassembling the motor.

Various modifications are, of course, possible within the scope of the invention. Thus, the tube 8 might be heated by heater wires wrapped around the tube, or carried into the tube by insulating connections, and connected to the motor windings in the manner shown, although these arrangements are probably less desirable than that shown because of the increased resulting overall diameters of the combined tube and heaters and the greater heating effect needed due to heat losses. The insulator 13 is necessary since the device 10 is mounted on the motor frame at ground potential and must, therefore, be insulated from any winding connected to the connector 18, unless the connector 18 is connected to a neutral point which is at ground potential. If the device 10 were insulated from ground, however, the insulator 13 could be omitted.

What we claim is:—

1. A polyphase dynamo electric machine having a thermally responsive protective device comprising tube means containing a liquid which vaporizes to actuate machine de-energising contacts at the safe

maximum temperature of the machine, the complete tube means being disposed in close thermal relation to the windings of all the phases of the machine so as to be heated by the heating effect of current flowing in said phases, and individual parts of said tube means being adapted to be individually and additionally heated by the currents flowing in the respective phases of the machine.

2. A machine as claimed in Claim 1 wherein the tube means consists of tube sections of electrically conducting material electrically connected with the circuits of the machine windings in such a way that separate portions of the tube carry the current of the associated phase winding.

3. A machine as claimed in Claim 2 wherein the tube means comprises two tube sections which are electrically insulated from each other but which have their bores communicating with each other, one section being substantially twice as long as the other section, both sections having electrical connecting means adjacent each end and the longer section having additional connecting means substantially midway between the ends thereof whereby the tube is divided into three substantially equal lengths which are connected in the winding circuit of the machine.

4. A machine as claimed in Claim 3 wherein the connecting means adjacent the free end of the shorter section of the tube is connected to one of the phase windings of the machine, the connecting means at the other end of said shorter section being connected to the connecting means midway of the longer section of the tube, the other two connecting means adjacent the ends of said longer section being respectively connected to the other two phase windings of the machine.

5. A machine as claimed in Claim 3 wherein one of the phase windings of the machine is connected to the connecting means adjacent the free end of the shorter section of the tube, a second one of the

phase windings of the machine being connected to the connecting means adjacent one end of the longer section of the tube, the other ends of said phase windings being connected together for connection to one phase of a three-phase line, one end of the third-phase winding of the machine being connected to the connecting means at the other end of the longer section of the tube, the other end of the third-phase winding and the other connecting means of the shorter section of the tube being connected together for connection to a second phase of the line, and the connecting means midway of the longer section of the tube being connected to the third phase of the line.

6. A machine as claimed in any of the preceding claims wherein said tube means extends circumferentially of the machine in close thermal relation with the end-ports of the stator windings.

7. A machine as claimed in any of the preceding claims wherein one end of said tube means extends outside the stator member of the machine and is provided with switch means for effecting de-energisation of the machine in response to vaporization of the liquid in the tube means.

8. A machine as claimed in Claim 7 wherein said switch means are accessible from the outside of the machine.

9. A machine as claimed in any of the preceding claims, wherein one end of the tube extends into close thermal relation with one of the bearings supporting the rotor of the machine.

10. A polyphase dynamo-electric machine having a thermally responsive protective device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

G. RAYMOND SHEPHERD,

Chartered Patent Agent,

1-3, Regent Street, London, S.W.1,
Agent for the Applicants.

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 SHEET 1

Fig. 1.

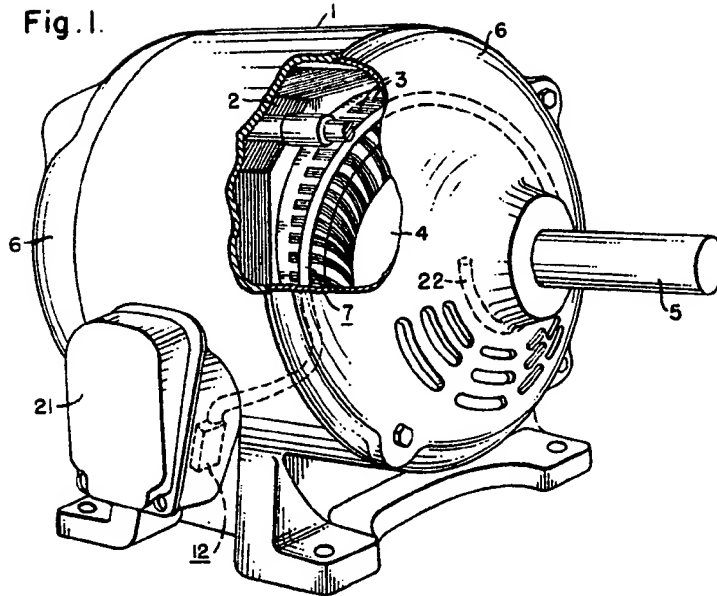
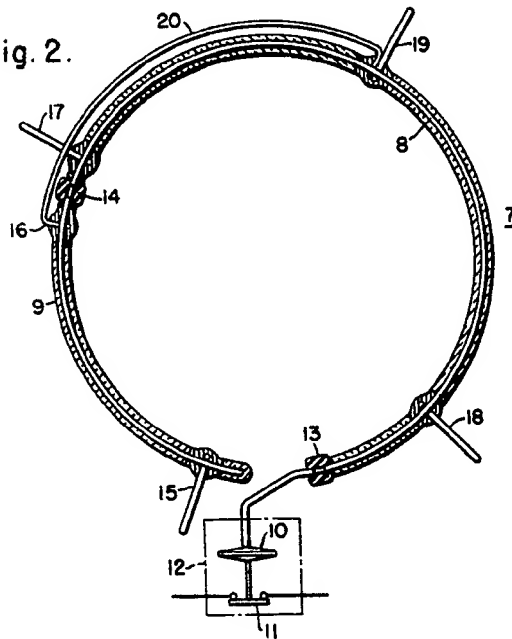
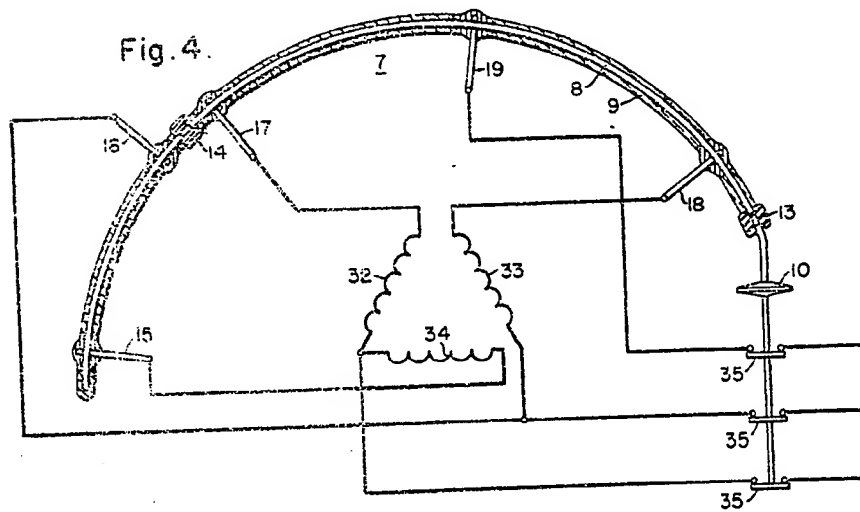
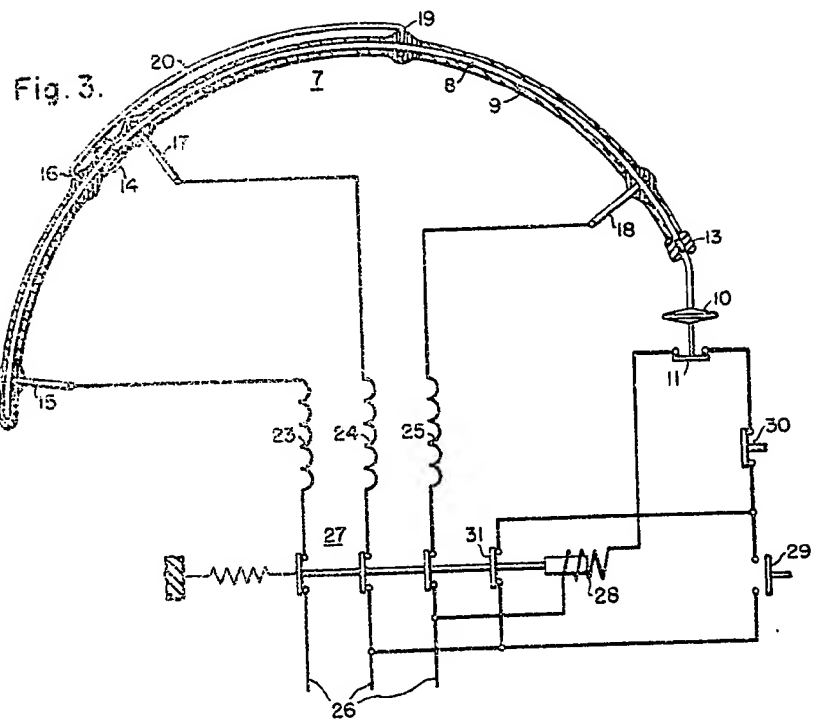


Fig. 2.



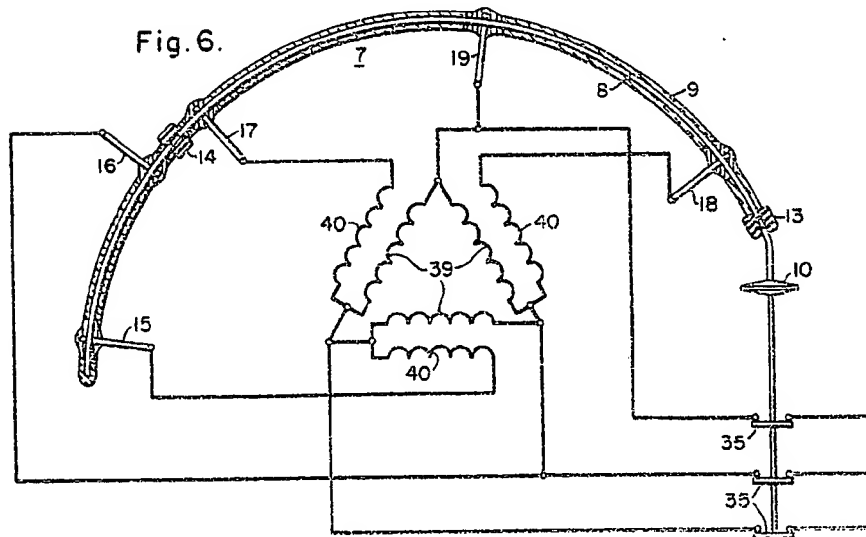
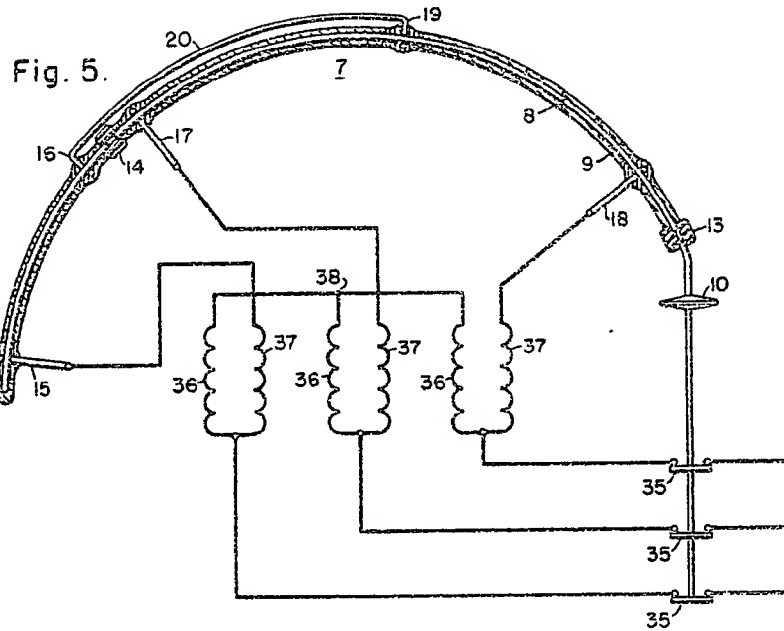


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SHEETS 2 & 3



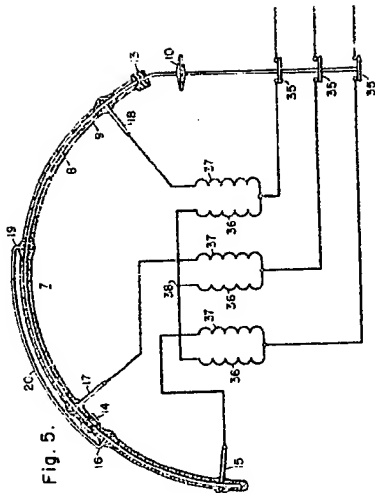
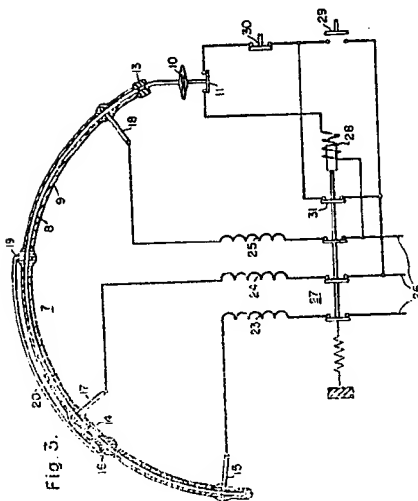


Fig. 5.



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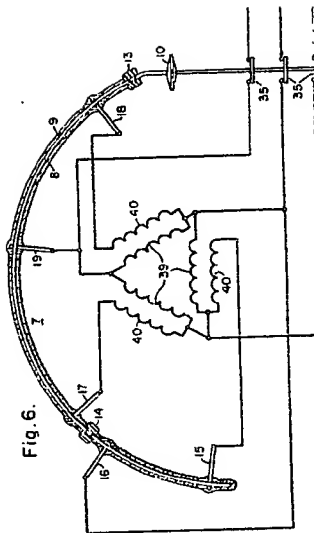


Fig. 6.

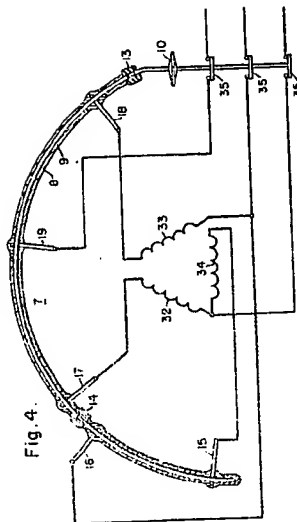


Fig. 4.

Fig. 1.

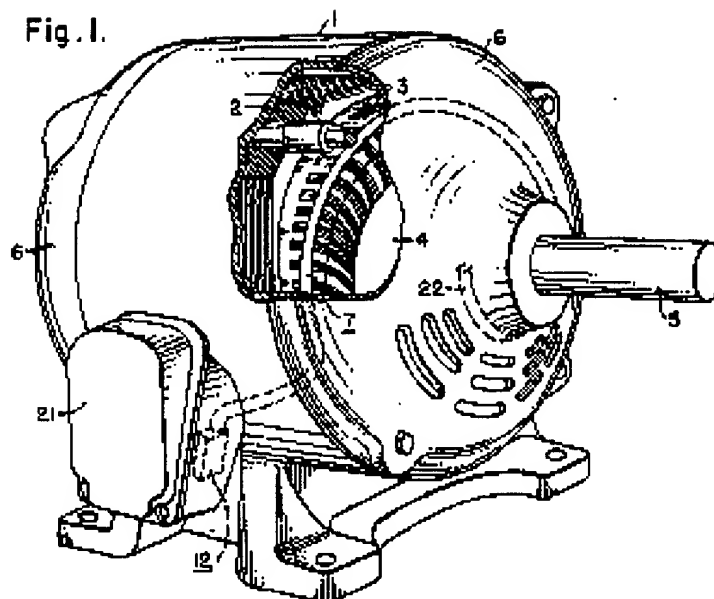
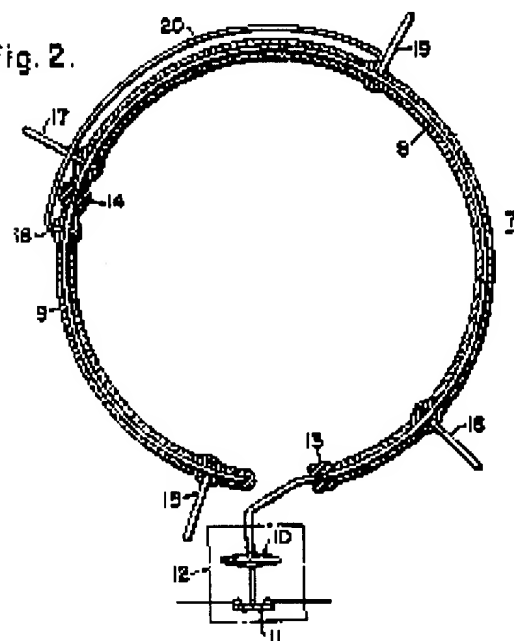
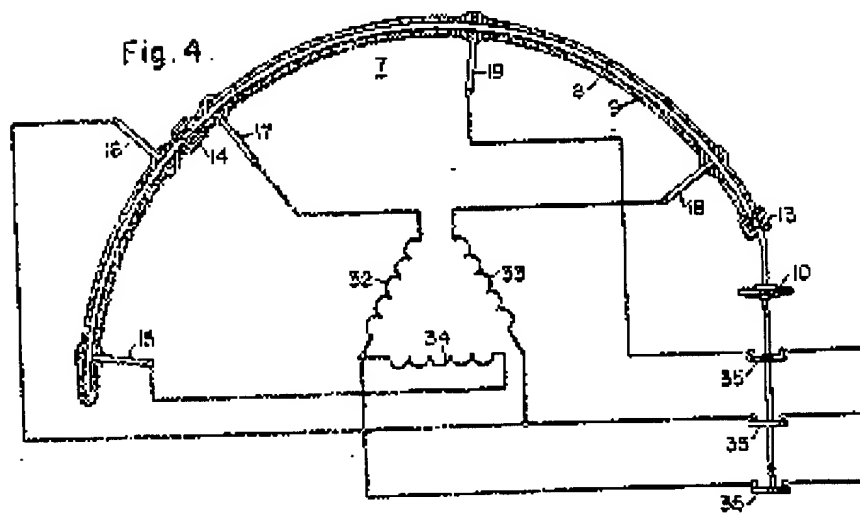
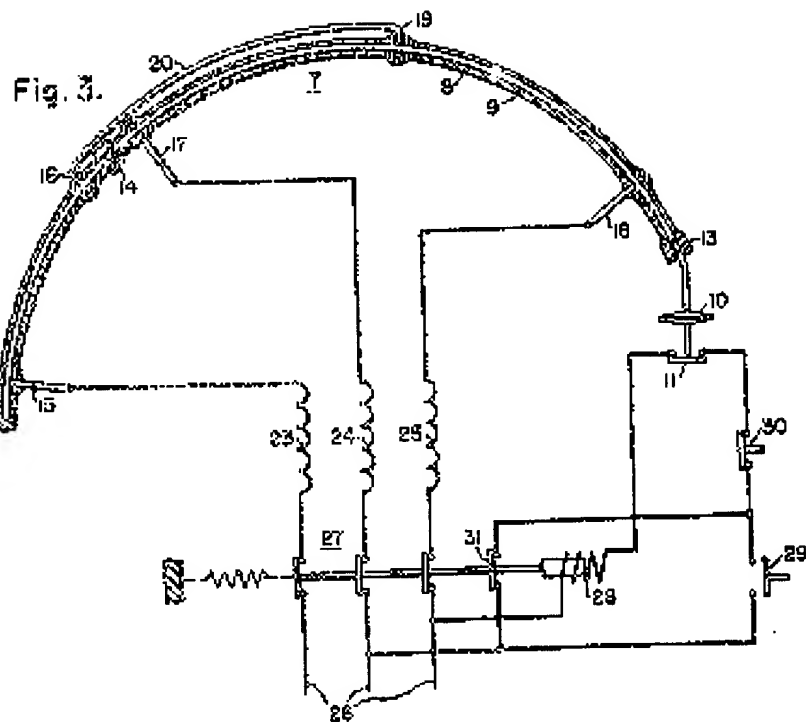


Fig. 2.

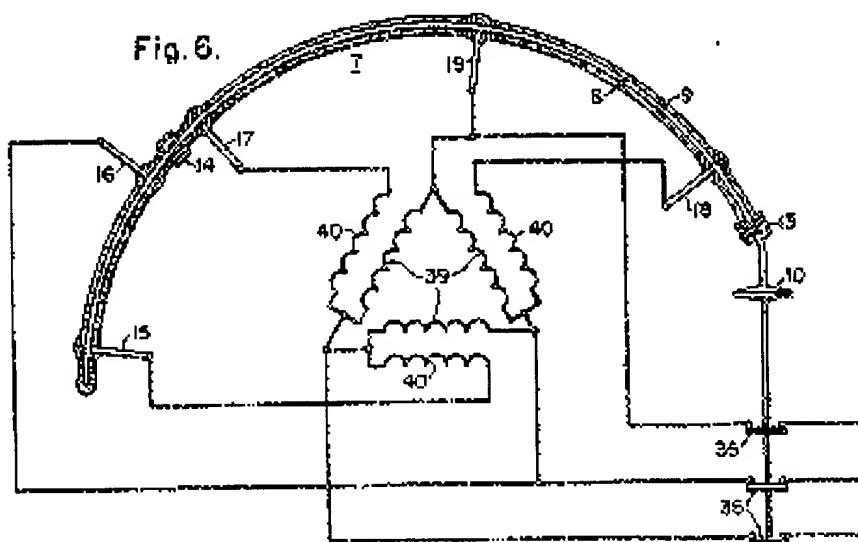
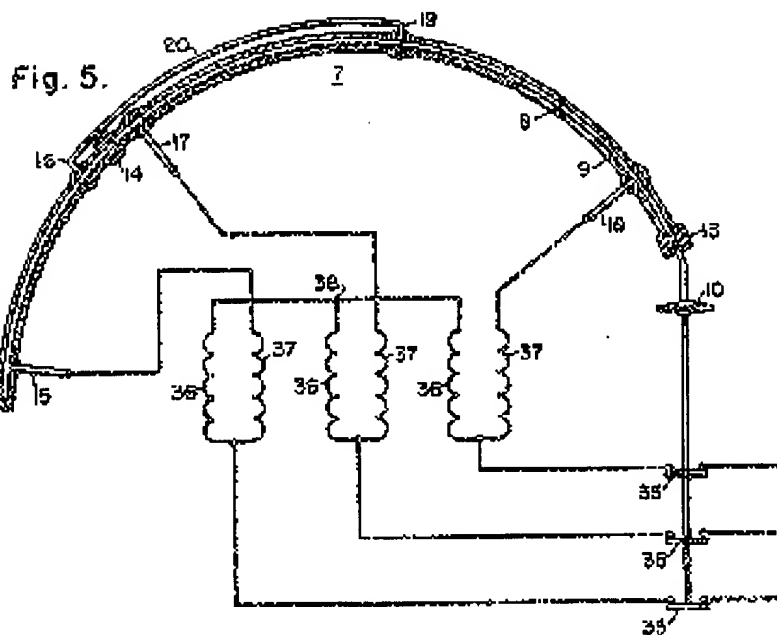




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SHEETS 2 & 3



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